

## Physics 122 Final Exam Room Assignments:

A-Can.	Humanities 1003
Car-Franc.	Humanities 1006
Franz-Hsu.	Javits 101
Hua-Mon.	Javits 102
Mor - K. Patel.	Javits 103
M. Patel - Sari.	Javits 109
Sarm - Tang.	Javits 111
Taq - Z.	Light Engineering 102

Review yesterday is available at

<http://echoserver.sinc.stonybrook.edu:8080/ess/echo/presentation/62925b89-f06a-4a54-84d7-ecc9c74f6427>.

I don't know what your letter grade is so far. Please do the best you can on the final exam.

You are responsible for constants, *e.g.*,

Speed of light  $c = 3 \times 10^8$  m/s

Electrical constant  $k_e = 9 \times 10^9$  (units)

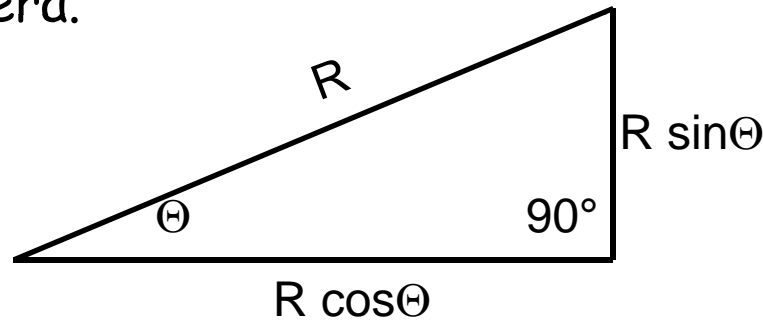
Atomic mass unit  $u = 1.66 \times 10^{-27}$  kg

$uc^2/e = 931.5$  MeV

**not a complete list**

You should know numerical prefixes: femto, pico, nano, milli, centi, kilo, mega, giga, tera.

Simple trigonometry



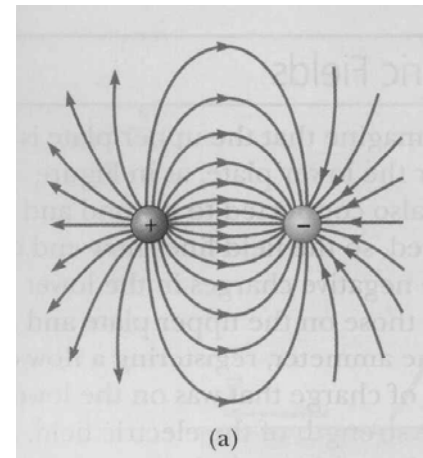
You should be adept at unit conversions and know (bring) all the numbers you need:

*e.g.*, what is the speed of light in miles per hour?

$$3 \times 10^8 \frac{\text{m}}{\text{s}} \times \frac{1 \text{ inch}}{0.0254 \text{ m}} \times \frac{1 \text{ foot}}{12 \text{ inch}} \times \frac{1 \text{ mile}}{5280 \text{ foot}} \times \frac{3600 \text{ s}}{1 \text{ hour}} = 6.71 \times 10^8 \frac{\text{miles}}{\text{hour}}$$

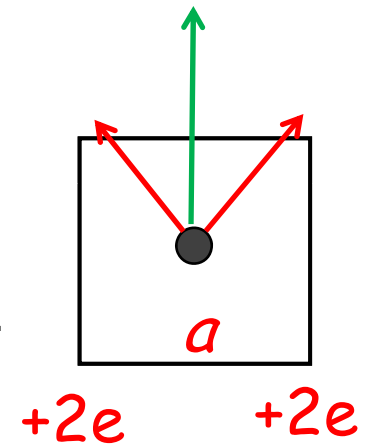
## Chapter 15. Key concepts.

- 1) Coulomb's law.  $\mathbf{F}$  has magnitude  $k_e q_1 q_2 / r^2$ .
- 2)  $\mathbf{F}$  is a vector, forces from multiple charges add to produce a net force.
- 3)  $\mathbf{F}$  is repulsive for like charges, attractive for unlike.
- 4)  $k_e = 9 \times 10^9 \text{ N m}^2 / \text{C}^2$ .
- 5) Fundamental charge  $e = 1.6 \times 10^{-19} \text{ C}$ .
- 6) electron charge =  $-e$ , proton  $+e$ , alpha  $+2e$ , nucleus  $+Ze$ .
- 7) Electric field: force that would be acting on a particular charge. Put a charge  $q$  in the vicinity of several other charges, work out the force  $\mathbf{F}$  from Coulomb. Define electric field as  $\mathbf{E} = \mathbf{F} / q$ .
- 8)  $\mathbf{E}$  points away from positive charges, towards negative charges.
- 9) Charge  $q$  feels a force  $\mathbf{F} = \mathbf{E} q$ . Same direction as  $\mathbf{E}$  if  $q > 0$ , opposite if  $q < 0$ .
- 10) Electric field lines: imaginary line in space that are everywhere tangent to the electric field. Lines are closer together in regions where the field is larger.



## Practice exam question #1

In the square shown ( 15 cm on a side) the two lower corners are occupied by alpha particles and the two upper corners are empty. The magnitude of the electric field at the center of the square is:



Treat each source separately, add fields as vectors.  
Distance from source to observer =  $a/\sqrt{2}$

Each  $E$  has magnitude  $k_e Q / r^2 = k_e 2e / (a^2/2)$   
 $= 4 k_e e / a^2$ .

Net  $E$  = vector sum has magnitude  $\sqrt{2}E$

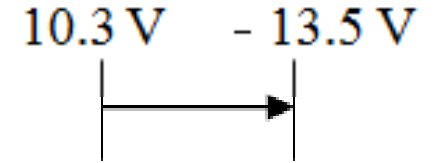
$$= \sqrt{2} \frac{4k_e e}{a^2} = \sqrt{2} \frac{4 \times 9 \times 10^9 \times 1.6 \times 10^{-19}}{0.15^2} = 3.62 \times 10^{-7} \text{ N/C}$$

## Chapter 16. Key concepts.

- 1) Electric potential: Potential energy of a "test charge  $q_0$ " /  $q_0$ .
- 2) Unit: Volt = Joule/Coulomb
- 3) Potential from one point charge  $V(r) = k_e Q / r$ .  $V(\infty)=0$ .
- 4) Lines of constant potential are perpendicular to electrical lines of force
- 5) The surface of a conductor is a surface of constant potential (move charge from one point to another without doing work), as long as there is not an external driving source of current.
- 6) There is no electric field inside a conductor, unless there is a driving source of current.
- 7) On a charged conductor, there are mobile charges that adjust themselves to insure 5) and 6)
- 8) Another energy unit: electron volt = eV = work to move elementary charge through potential difference of one Volt =  $1.6 \times 10^{-19}$  Joule.
- 9) Battery: source of potential difference
- 10) Capacitor: 2 separated conducting plates.  $Q = VC$ . Farad = Coul./Volt
- 11) Make a capacitor:  $C = \kappa (4\pi k_e)^{-1} A/d$
- 12) Energy stored in capacitor =  $\frac{1}{2} C V^2$ .

### Practice Exam Question #2

An electron travels from the left to the right potential shown. The change in potential energy of the electron is

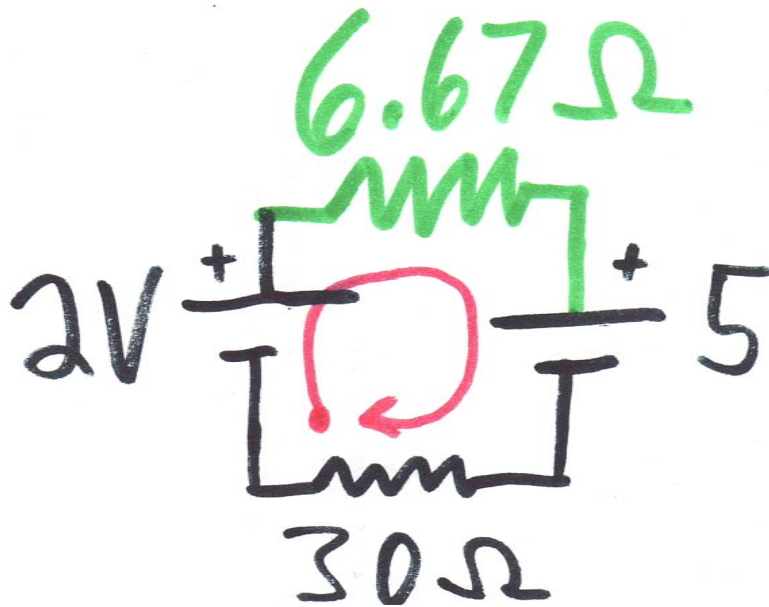
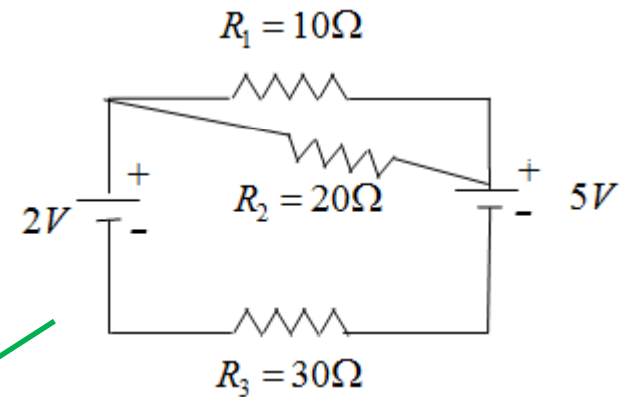


$$\begin{aligned}\text{Change} &= \text{final} - \text{initial} = (-e) \times (-13.5) - (-e) \times (10.3) \\ &= 1.6 \times 10^{-19} \times (13.5 + 10.3) = 3.81 \times 10^{-18} \text{ Joule} \\ &(\text{SI units throughout})\end{aligned}$$

## Chapter 17. Key concepts.

- 1) Electric current  $I$  (Ampere) = Coulomb / Second
- 2) Resistance. Unit = Ohm. Current flows through a wire, voltage difference between ends  $V = I R$ , where  $I$  is current through wire.
- 3) Resistivity - property of material.  $R = \rho L / A$
- 4) Charge carriers in a metal are actually negative electrons, so electrons move in direction opposite current.
- 5) Power dissipated in circuit = Voltage  $\times$  Current. (Watt = Volt  $\times$  Amp)
- 6) Real batteries have internal resistance
- 7) Same current flows through circuit elements in series.
- 8) Same voltage appears across circuit elements in parallel.
- 9) Effective resistance:  $R = R_1 + R_2$  series,  $R = 1/(1/R_1 + 1/R_2)$  parallel.
- 10) More complicated circuits: Kirchhoff's rules. Sum of all currents into a junction = 0. Sum of all potential changes around a loop = 0.
- 11) Signs: Potential increases (more positive) if you move from the (-) to the (+) terminal of a battery. Potential decreases (more negative) if you move through a resistor in the direction of current flow.

#3. In the circuit shown, the current through the 2V battery is:



$$0 = +2 - 6.67 I - 5 - 30 I = -3 - 36.67 I$$

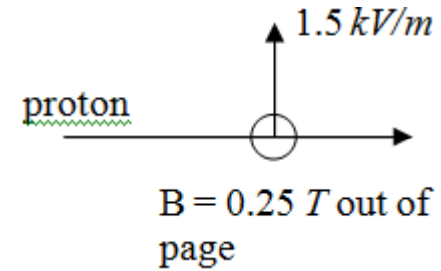
$$I = -0.082 A$$

Negative sign means current flows opposite the direction I guessed. Magnitude is correct.

## Chapter 18. Key concepts.

- 1) Magnetic Field. Generated by electrical current. (Permanent magnets have internal atomic currents). Unit Tesla
- 2) Magnetic force on a moving charge =  $q v B \sin \theta$
- 3) Magnetic force on a current - wire of length  $L$ . =  $I L B \sin \theta$
- 4) Direction given by right hand rule. Perpendicular to both  $v$  and  $B$ , turn right hand fingers from  $v$  to  $B$ , thumb points in direction of  $F$ .
- 5) A permanent magnet has field lines that point from North to South pole.
- 6) Note force has opposite direction for negative  $q$ . Force on a given current is independent of the sign of charge carriers.
- 7) Uniform magnetic field bends a particle into a circle of radius  $r = mv/qB$ .
- 8) Magnetic field produces a torque on a current loop  $\tau = I A B \sin \theta$
- 9) Magnetic field is generated by currents.  $\Delta B = k' I \Delta L / r^2$ ,  $k' = 10^{-7} \text{ Tm/A}$
- 10) Direction of field is perpendicular to current and to line from current. Field lines wrap around a current. Point right hand thumb in direction of current, fingers wrap in direction of field.
- 11) Simple configuration 2. Center of a single loop.  $B = 2\pi k' I / r$ . Wrap fingers in direction of current flow, thumb points in direction of  $B$ .
- 12) Simple configuration 2. Inside a long solenoid,  $N/L$  turns/length. uniform  $B = 4\pi k' I N / L$ .
- 13) Magnetic moment of a current loop  $\mu = I A$ , direction perpendicular to plane of loop. Torque  $\tau = \mu B \sin \theta$ . Potential energy =  $-\mu B \cos \theta$ .

#4. The velocity of the proton which travels undeflected through the crossed electric and magnetic fields as shown is:



Proton = positive charge  $e$

Electric force =  $e E$  (up)

Magnetic force =  $e v B$  (down)

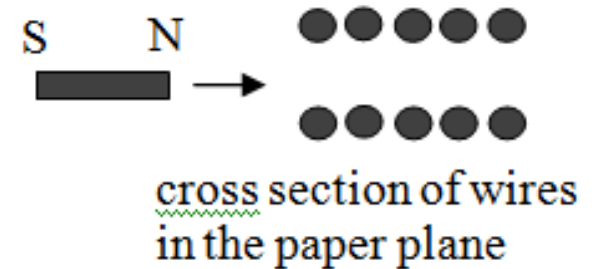
They are equal in magnitude, so  $v = E / B = 1500 / .25 = 6000 \text{ m/s}$ .

Note that answer does not depend on sign of charge.

## Chapter 19. Key concepts.

- 1) Magnetic flux through a closed loop.  $\Phi = B A \cos\theta$ , where  $\theta$  is the angle between the field and the normal to the loop (direction perpendicular to the plane of the loop.)
- 2) If a flux  $\Phi$  is changing, there is an induced electromotive force (voltage) around the loop  $= -\Delta\Phi/\Delta t$ . If circuit has  $N$  turns,  $= -N\Delta\Phi/\Delta t$ .
- 3) - sign is Lenz's law. Induced EMF acts to counteract the **change** in  $B$ .
- 4) Flux can change by changing  $B$ ,  $A$ , or  $\theta$ .
- 5) Rotate a loop of  $N$  turns in a uniform field (in the direction that the flux changes), induces voltage  $\omega N B A \sin\omega t$ , peak  $\omega N B A$ . (Remember that  $\omega$  is angular frequency - radians per second.)
- 6) Transformer. Two coils of wire with  $N_1$  (primary),  $N_2$  (secondary) turns arranged so that they share all magnetic flux. Connect primary to a source of alternating voltage, and a voltage will appear at the secondary  $V_1/V_2 = N_1/N_2 = I_2/I_1$  (for ideal transformer - no loss of energy).
- 7) Inductance. Coil of wire has a flux from its own magnetic field.  
 $V = L \Delta I/\Delta t$ . Unit of  $L =$  Henry.
- 8) Energy stored in an inductor is  $\frac{1}{2} L I^2$ .
- 9) Transverse electromagnetic waves (light, radio) propagating at a speed  $c = 3 \times 10^8$  m/s are a prediction and a consequence of the physical laws of electromagnetism.

#5. In your lab, you insert a bar magnet with the north pole on the right end of the bar into a coil as shown. The current in the coil:



In the coil, the field points to the left at the time illustrated, and it is increasing. Induced current flows to counteract that, i.e., produce a field pointing to the left. By right hand rule, that current flows into the plane of the board at the top, out at the bottom. Choice C.

Reject other possibilities:

Current is proportional to the speed that magnet is inserted.

If magnet is withdrawn, the field is decreasing, so the induced current flows the opposite direction to try to keep it constant, pointing to the right.

### Practice Exam #7

A coil of wire with 500 turns in a circle of 3 cm radius is in the horizontal plane. A magnetic field of 0.035 Tesla is oriented vertically (perpendicular to the plane of the loop). The mad scientist who operates the magnet reduces its field to zero and then increases it to 0.035 Tesla pointing in the opposite direction, in a total time of 5 seconds. What is the induced voltage produced in the coil during this time?

$$\text{Initial flux} = \pi r^2 B = \pi \times 0.03^2 \times 0.035 = 1.0 \times 10^{-4} \text{ Tm}^2$$

$$\text{The flux reverses, so } \Delta\Phi = 2.0 \times 10^{-4} \text{ Tm}^2$$

$$\text{EMF} = N \Delta\Phi / \Delta t = 500 \times 2 \times 10^{-4} / 5 = 0.02 \text{ Volt.}$$

Note - previously written as 0.032. Sorry.

## Chapter 20. Key concepts.

- 1) Time-varying currents & voltages in circuits made of resistors, capacitors, and inductors.
- 2)  $V = I R$ .  $V = L dI/dt$ .  $I = C dV/dt$ .
- 3) RC circuit: time constant  $\tau = RC$ . After a long time, current = 0.
- 4) Battery charging capacitor through resistor.  $V(t) = V_{\text{batt}}(1 - e^{-t/RC})$ .  
 $I(t) = V_{\text{batt}}/R e^{-t/RC}$ . Capacitor discharging through resistor  $V(t) = V_0 e^{-t/RC}$ .
- 5) Alternating current. Frequency  $f = \omega/2\pi$ .
- 6) RMS voltage and current indicate how much work an alternating voltage or current can do.  $V_{\text{rms}} = V_{\text{peak}}/2^{1/2}$ .  $I_{\text{rms}} = I_{\text{peak}}/2^{1/2}$ .
- 7) Ohm's law holds for rms voltage and current as well as DC or peak.
- 8) Average power in a circuit is  $V_{\text{rms}} \times I_{\text{rms}} = V_{\text{rms}}^2/R = I_{\text{rms}}^2 R$ .
- 9) AC in an inductor or capacitor, current is not in phase with voltage.
- 10) In a capacitor  $V_{\text{rms}}/I_{\text{rms}} = V_{\text{pk}}/I_{\text{pk}} = X_C = 1/(2\pi f C)$ . Current lags  $\frac{1}{4}$  cycle behind voltage.
- 11) In an inductor  $V_{\text{rms}}/I_{\text{rms}} = V_{\text{pk}}/I_{\text{pk}} = X_L = 2\pi f L$  Current leads  $\frac{1}{4}$  cycle ahead of voltage.
- 12) Series RLC circuit. Impedance  $X = \sqrt{R^2 + (\omega L - 1/\omega C)^2}$
- 13) Resonance. Minimum impedance occurs at  $2\pi f = \omega = (LC)^{-1/2}$

### Practice Exam #8.

A capacitor is charged to 100 volts, and then connected to a resistor of  $2 \times 10^5$  Ohm. One second later, the capacitor voltage is 1 volt. What is the value of the capacitor?

$$V(t) = V_0 e^{-t/RC}$$

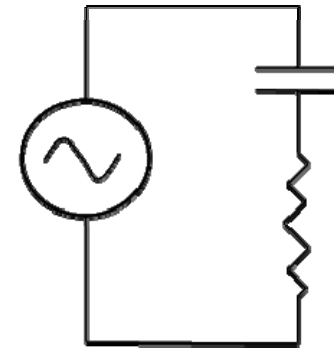
$$\frac{1 \text{ Volt}}{100 \text{ Volts}} = e^{-t/RC}$$

$$\ln\left(\frac{1}{100}\right) = -4.605 = -t / RC$$

$$C = \frac{t}{4.605R} = \frac{1 \text{ sec}}{4.605 \times 2 \times 10^5 \text{ Ohm}} = 1.08 \times 10^{-6} \text{ Farad}$$

## Practice Exam #9

If I double the frequency that is driving the series RC circuit shown, the impedance will:



Initial impedance  $Z_i = \sqrt{R^2 + 1/(\omega C)^2}$

After doubling  $\omega$   $Z_f = \sqrt{R^2 + 1/(2\omega C)^2}$

Clearly  $Z_f$  is smaller than  $Z_i$ , because we are adding a smaller number inside the square root. Just a little bit smaller if  $R$  is much larger than  $1/(\omega C)$ . A bit more than half as large if  $R$  is very small. So the correct answer is that it will decrease, but will be more than half the original value. Answer is C. I am sorry that the answer I originally posted (B) is wrong, and I have corrected posted answers.

## Chapter 21. Key concepts.

- 1) Light is a wave moving in vacuum at  $3 \times 10^8$  m/s
- 2)  $\lambda = c / f$ .
- 3) In other media,  $v = c / n$ . Where  $n$  = index of refraction, generally  $> 1$ .
- 4) Huygens's principle - propagation of wave fronts
- 5) Reflection - reflected wave has same angle as incident wave
- 6) Refraction. Snell's law.  $n_1 \sin \theta_1 = n_2 \sin \theta_2$ . Remember to measure  $\theta$  from the normal (perpendicular) to the surface.
- 7) Dispersion.  $n$  can depend on wavelength.
- 8) Total internal reflection. Light in higher index ( $n_2$ ) medium cannot escape if incident angle  $\theta_2 > \arcsin(n_1/n_2)$
- 9) Polarization. Normal light is unpolarized. Half of unpolarized light will pass through an ideal polarizer, and emerge polarized.
- 10) Malus's law. Transmitted intensity = Incident Intensity  $\times \cos^2\theta$
- 11) Interference from two thin slits separated by distance  $d$ . Intensity at angle  $\theta$  is a maximum if  $m\lambda = d \sin\theta$  for integer  $m$ .
- 12) Diffraction from a single slit of width  $b$ . Intensity at angle  $\theta$  is a maximum if  $m\lambda = d \sin\theta$  for  $m = 0, \pm 1.5, \pm 2.5, \dots$ . Minimum for  $m = \pm 1, \pm 2, \dots$
- 13) Diffraction from circular aperture of diameter  $D$ . Rings. First dark ring at  $\theta = 1.22 \lambda / D$ . Angular resolution of optical device with lens aperture  $D$ .
- 14) Diffraction from many equally spaced ( $d$ ) slits. Sharp maxima at  $m\lambda = d \sin\theta$  for integer  $m$ .

Practice exam #10.

Light with a wavelength of 550 nm in vacuum enters a piece of glass, where the index of refraction is 1.33.

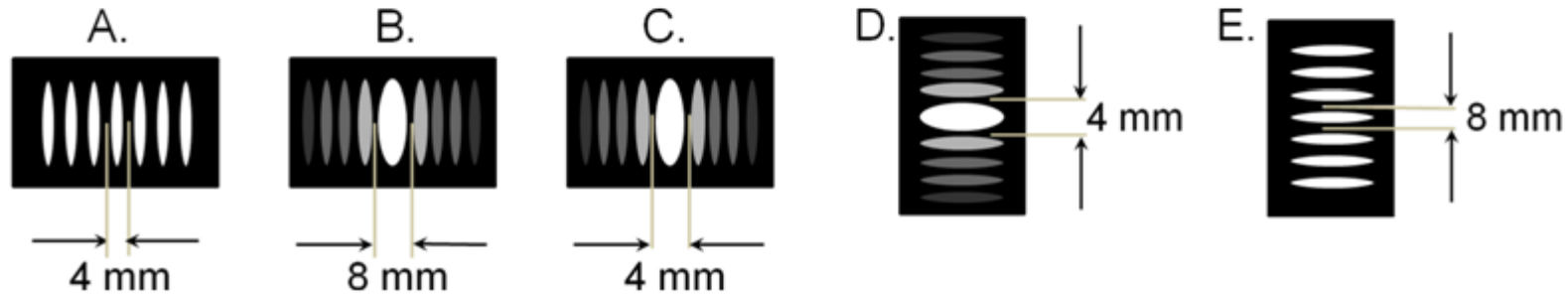
Which of the following statements is correct?

- The frequency in glass is  $7.25 \times 10^{14}$  Hz
- The frequency in glass is  $1.83 \times 10^{-15}$  Hz
- The frequency in glass is  $4.10 \times 10^{14}$  Hz
- The wavelength in glass is 731 nm
- The wavelength in glass is 414 nm

Eliminate choices with frequency: the frequency in glass is the same as in vacuum:  $f = c/\lambda = 5.45 \times 10^{14}$  Hz.

$$\lambda_{\text{glass}} = \lambda_{\text{vacuum}} / n = 550/1.33 = 414 \text{ nm.}$$

6. In one of your labs, light from a laser shone on a hair, making a pattern on a wall. If the hair is oriented vertically, the laser has a wavelength of 650 nm, the hair has a diameter of 130  $\mu\text{m}$ , and the wall is 80 cm from the hair, which of these looks the most like the pattern you observe?



Single slit diffraction. First dark line occurs for  $m = 1$ .  
 Single slit equation:  $\sin\theta = x / D = m\lambda / b$ , so  
 $x = 1 \times 0.80 \times 650 \times 10^{-9} / 0.00013 = 4\text{mm}$

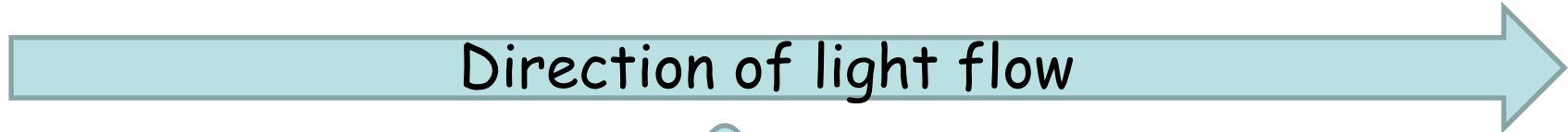
Correct answer is B

## Chapter 22. Key concepts.

- 1) Geometrical optics - topics understood by tracing rays of light in straight lines, reflected or refracted by lenses.
- 2) Plane mirror - image appears to be behind the mirror - there is not actually an image there, but rays diverge as if from a virtual source.
- 3) Spherical mirrors. Analysis for rays close to axis, small angles.
- 4) Spherical mirror. Object distance  $O$ , image distance  $I$ , mirror radius  $R$  are related by  $1/O + 1/I = 2/R$ . Distances are positive for object or image on the reflecting side of the mirror.  $R$  positive for concave, negative convex. Focal length  $f = R/2$ .
- 5) Lenses. Same relation by  $1/O + 1/I = 1/f$  holds, but sign convention is slightly different. See following page for description of real vs. virtual.
- 6) Magnification  $M = -I/O$ . Positive for rightside up, negative inverted.  $>1$  or  $< -1$  if image is larger than object.
- 7) Lensmaker equation  $1/f = (n-1)(1/R_1 + 1/R_2)$  with  $R$  positive if convex (bulging out from center), negative if concave (caved in towards center of lens) on each side.
- 8) Examples: magnifying lens, camera, slide projector.
- 9) Corrective lens: produce a virtual image at a position where the eye can focus
- 10) Microscope - 2 converging lenses with real image between
- 11) Telescope - angular magnification of distant object =  $f_{obj}/f_{eyepiece}$ .

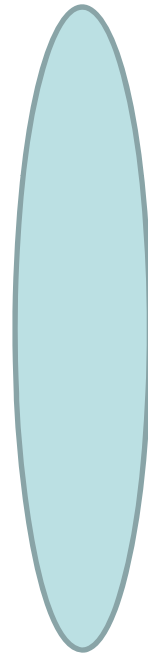
# SIGN CONVENTION of IMAGE and OBJECT DISTANCES for LENSES

(This is important, and it makes sense. Remember it!)



Real object.  
Positive object  
distance  
 $O > 0$

Virtual Image  
Negative image  
distance  
 $I < 0$



Lens:  
Converging  $f > 0$   
Diverging  $f < 0$

Real Image  
Positive image  
distance  
 $I > 0$

Virtual Object  
Negative object  
distance  
 $O < 0$

# SIGN CONVENTION of IMAGE and OBJECT DISTANCES for MIRRORS

(This is important, and it makes sense. Remember it!)

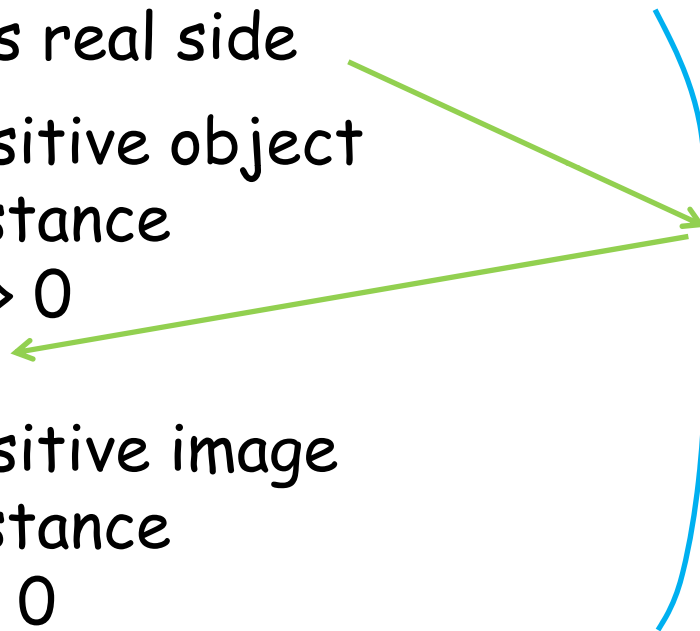
All of the light is on  
this real side

Positive object  
distance

$$O > 0$$

Positive image  
distance

$$I > 0$$



Virtual side

Negative image  
distance

$$I < 0$$

Negative object  
distance

$$O < 0$$

Mirror:

concave  $f > 0$  (makeup mirror)

convex  $f < 0$  (rear-view on passenger side)